Digestion and Absorption along the GIT

ILOs

1. **Describe the Stages of Digestion**
2. **Summarize the digestion and mechanism of absorption of different nutrients (carbohydrate and protein, along GIT (transport carriers).**
3. **Apply knowledge to solve clinical problem**

What is digestion?

It is the process essential for conversion of food into a small and simple form.
Or : breakdown of food molecules into smaller subunits, simple components, to be absorbed through the intestinal wall.

Stages of digestion:

Digestion occurs in the GIT lumen both mechanically and chemically.

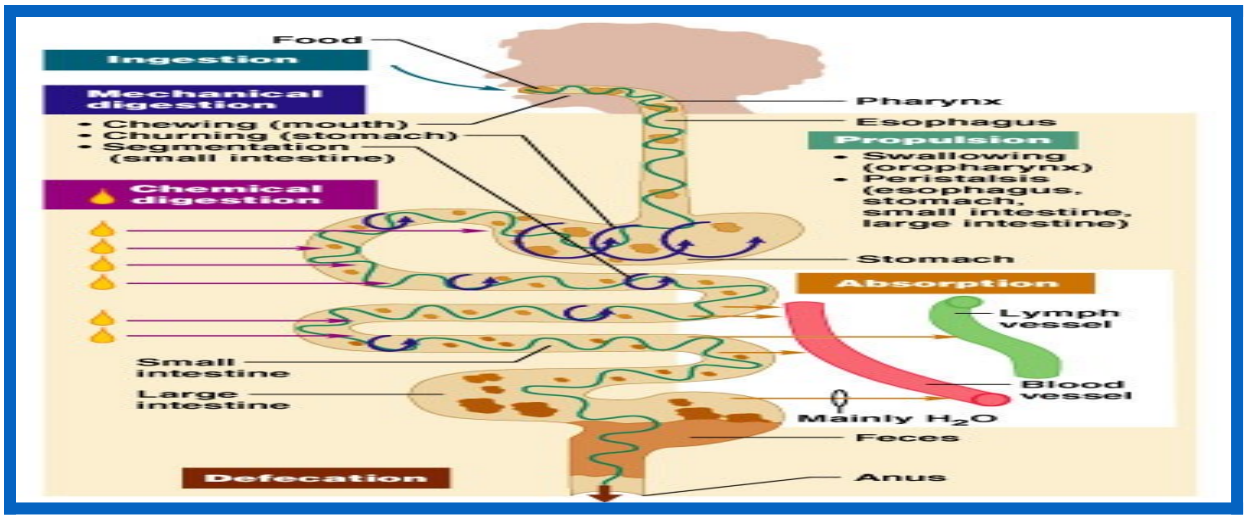
Mechanical digestion: It is Physical breakdown of food → smaller particles

Mouth "teeth" → Chewing.
Stomach → Churning action.
Small intestines → Segmentation movement.

Chemical digestion: It is series of hydrolysis reactions by enzymes "from saliva, stomach, pancreas and intestines" → small particles→ to be easily absorbed

Carbohydrates → monosaccharides
Proteins → amino acids
Fats → glycerol & fatty acid

- Enzymes catalyze hydrolysis when:-
  - ✓ Correct substrate is available
  - ✓ pH is optimal
  - ✓ Temperature is optimal
- GIT secretions → optimize the environment for digestion



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What is absorption ?

- It is the process of transporting (Passage) of small digested end products (nutrients) from the lumen of the gut into blood stream or lymphatic vessel
- Some absorption takes place in the mouth, stomach, small and large intestine

Small intestine is the primary site for digestion and absorption ≈ 90% of food

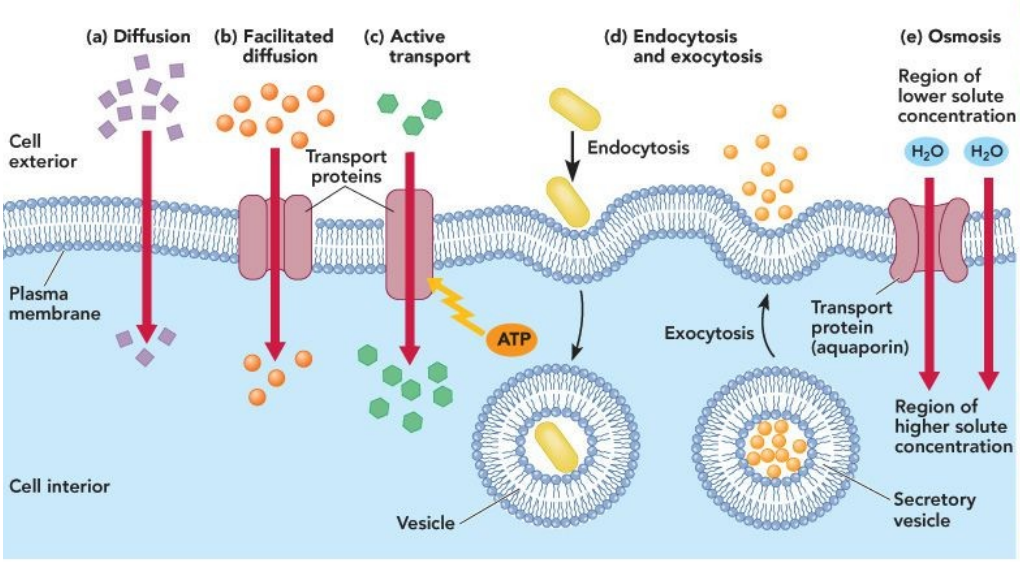
What are different mechanisms involved in absorption?

a) Along intestinal wall:

1) Simple diffusion
2) Facilitated diffusion
3) Active transport
4) Endocytosis
5) Osmosis

b) Then nutrients follow one of 2 roots:

1) Water soluble substances is absorbed to GIT capillaries → portal vein → liver.
2) Fat soluble substances is absorbed to GIT lymph capillaries → lymphatic vessels → thoracic duct → systemic circulation.



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Digestion and absorption of carbohydrates

Digestion :

Source	Enzyme	Activator	Substrate	Products
Salivary glands	Salivary α -amylase	Cl^-	Starch	Maltose and dextrins
exocrine pancreas	α -amylase	Cl–	Starch	dextrins, maltotriose, and maltose
Intestinal mucosa	Maltase	. . .	Maltose, maltriose α dextrins	Glucose
	Lactase	. . .	Lactose	Galactose and glucose
	Sucrase	. . .	Sucrose; maltriose maltose	Fructose and glucose
	α-Dextrinase	. . .	α-Dextrins, maltose	Glucose

			maltriose	
	Trehalas	. . .	Trehalose	Glucose

Absorption:

1) At luminal border:

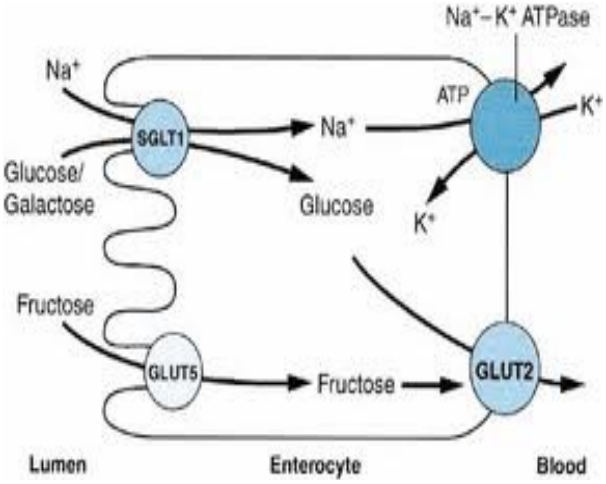
a) Glucose and galactose is absorbed by 2ry active transport through SGLT1.

b) Fructose is absorbed by facilitated diffusion through GLUT5.

c) Pentoses is absorbed by simple diffusion.

2) At basal border :

All monosaccharides are transported by GLUT2 to capillaries.



N.B.:

No limit for CHO absorption per day as long as we have electrochemical gradient for Na^{+}.

N.B.:

Glucose transporters :

Glucose enters cells either by facilitated diffusion or by secondary active transport with Na^{+}.

Seven different glucose transporters named GLUT 1–7 and 2 Na^{+} dependent transporters (SGLT1 &2)

Type of transporter	Site	Mechanism of transport	Transport depend on :
SGLT1	Intestine - Kidney	2ry active transport	Na^{+} concentration gradient
SGLT2	Kidney	2ry active transport	Na^{+} concentration gradient
GLUT2	Beta cell of pancreas -	Facilitated diffusion	None
GLUT4	Muscle- adipose tissue	Facilitated diffusion	Insulin dependent
GLUT5	Intestine	Facilitated diffusion	None

Applied physiology:

1) Infants with GLUT 1 deficiency have defective transport of glucose across the blood–brain barrier. They have low cerebrospinal fluid glucose in the presence of normal plasma glucose, seizures, and developmental delay.
2) Incretins and DPP4 inhibitors:
   - ✓ After intake of a meal and before blood glucose level increases, released GIT hormones cause release of insulin from β cell of pancreas “anticipatory increase”.
   - ✓ The most potent hormones enhance the release of insulin are GLP-1 and GIP.
   - ✓ Theses hormones are called *incretins* that affect endocrine pancreas of normal and diabetics.
   - ✓ DPP4 are enzymes present on cell surfaces that degrade the incretins
   - ✓ New line of drugs for diabetes is DPP4 inhibitors that enhance insulin release.

Digestion and absorption of proteins

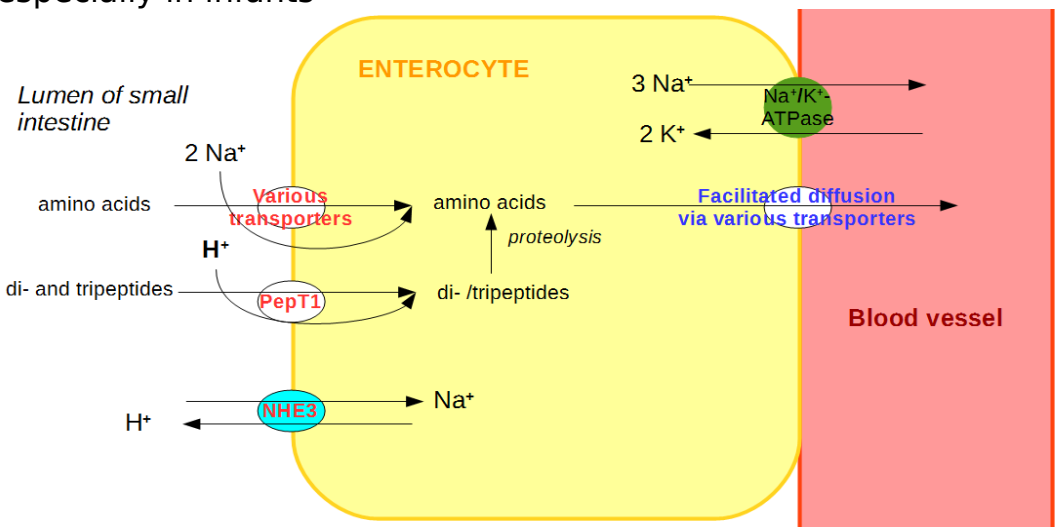
Digestion :

Source	Enzyme	Activator	Substrate	Product or catalytic functions
Stomach	**Pepsins (Pepsinogen)**	**HCL**	**Proteins and polypeptides**	**Cleave peptide bond**
Exocrine pancreas	**Trypsin (trypsinogen)**	**Entero-peptidase**	**Proteins and polypeptides**	**Cleave peptide bonds on of basic amino acids**
	Chymotrypsins (chymotrypsinogens)	**Trypsin**	**Proteins and polypeptides**	**Cleave peptide bonds on aromatic amino acids**
	Elastase	**Trypsin**	**Elastin,**	**Cleaves bonds on**

	(proelastase)		**some other proteins**	**aliphatic amino acids**
	Carboxy-peptidase A (Procarboxy-peptidase A)	**Trypsin**	**Proteins and polypeptides**	**Cleave carboxyl terminal amino acids**

Absorption of proteins:

- ✓ The source of proteins is either endogenous (digestive enzymes, sloughed mucosa and proteins leak from capillaries) or exogenous dietary proteins.
- ✓ Proteins absorbed either in form of amino acids, di or tri peptides.
- ✓ Most of amino acids are absorbed by Na^+ dependent secondary active transport at luminal border dependent on Na^+ concentration gradient created by active Na^+-K^+ pump at basal border.
- ✓ Amino acids at basal border are absorbed to blood capillaries by facilitated diffusion.
- ✓ Few amino acids are absorbed by facilitated diffusion at luminal border i.e. not Na^+ dependent.
- ✓ Dipeptides and tripeptides are absorbed by H^+ dependent cotransporter (pept-1)at luminal border. Then they are digested inside the cells and the amino acids are absorbed by facilitated diffusion at basal border.
- ✓ Small amount of proteins are absorbed as a whole by endocytosis especially in infants



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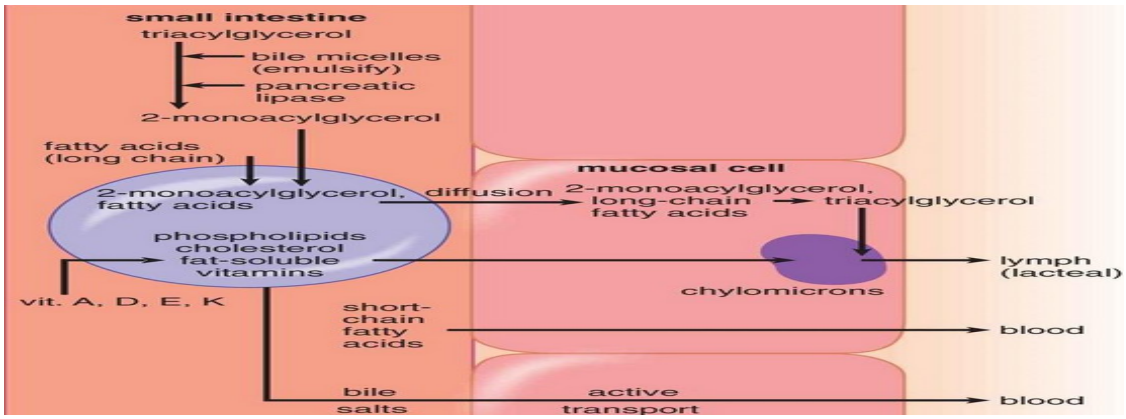
Digestion and absorption of fats

Digestion and absorption:

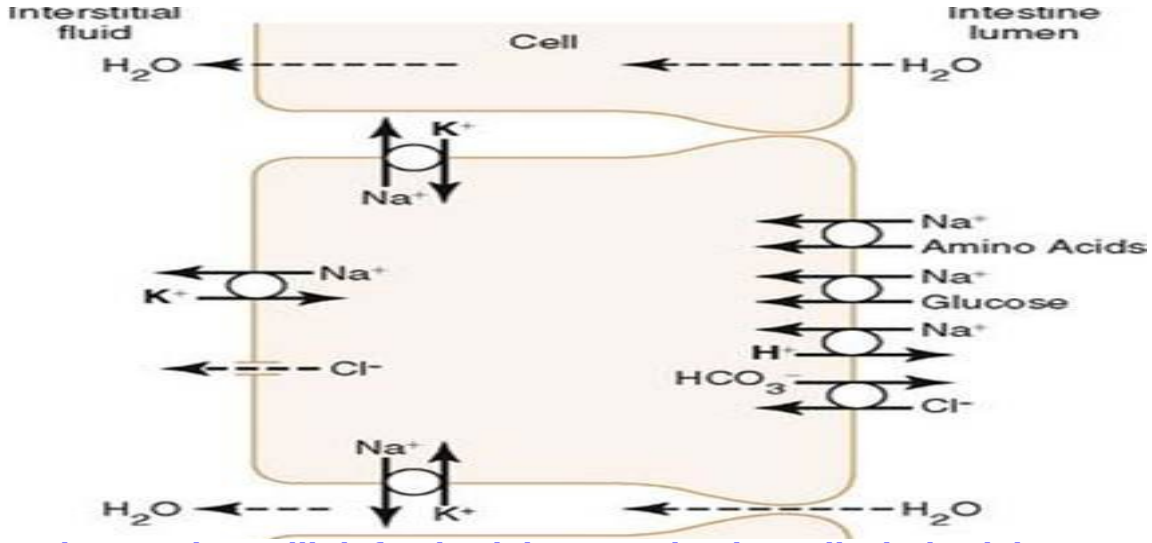
- ✓ Fats are digested by gastric and pancreatic lipase down to monoglycerides and fatty acids.
- ✓ Digestion products are grouped and surrounded by bile salts to form micelles that approach the luminal border of enterocytes.
- ✓ At luminal border of enterocytes, monoglycerides and fatty acids leave the micelles and enter enterocytes by diffusion through lipid bilayer.
- ✓ Inside the cell, the products are resynthesized into triglycerides that aggregates and coated by lipoproteins to form chylomicrons.
- ✓ Chylomicrons are transported by exocytosis into interstitial fluid then to central lacteals.
- ✓ From central lacteals, they reach the thoracic duct and then systemic circulation.
- ✓ Small amount of short and medium sized chain fatty acids is absorbed directly to blood stream (as they are more water soluble).
- ✓ Bile salts are mostly absorbed from ileum by Na^+- bile salt cotransporter.



Absorption of Sodium

Sodium is absorbed after meal intake coupled with nutrients (glucose and amino acids. And in between meals is absorbed coupled by electrolytes.

- ✓ *After meal intake*, Na^+ is absorbed by cotransporters at luminal border with other nutrients.
- ✓ *In between meals*, Na^+ is absorbed in exchange with H^+ while Cl^- is in exchange of HCO_3^- . NaCl is absorbed in exchange for H/HCO3 excretion (electroneutral mechanism in small intestine and colon.)
- ✓ Then Na^+ is pumped at basal border by Na^+- K^+ pump.



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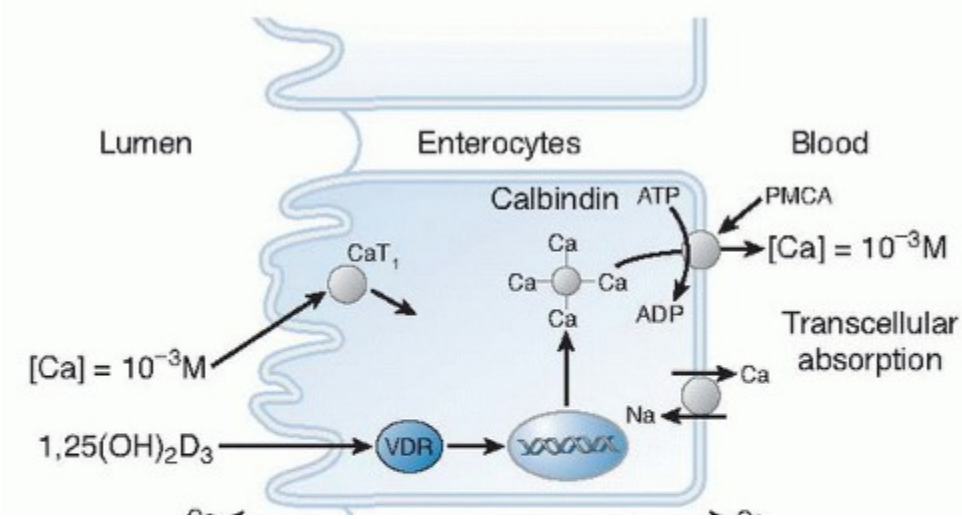
Absorption of Chloride

It occurs passively following electrical gradient created by active transport of Na^+ through a luminal chloride channel. (Cl^- channel is the site of action of vibrio cholera toxins)
Also, it occurs by electroneutral mechanism for Na^+ absorption.

Absorption of Calcium

It occurs according to body needs.

- ✓ *At luminal border*: it is absorbed through Ca^{++} specific channel. Then it binds to intracellular protein called calbindin.
- ✓ *At basal border*: it is transported by active process using Ca^{++} ATPase or secondary active transport using Na^+- Ca^{++} antiport.



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Ca^{++} absorption is increased in case of :

- ✓ Increased body needs
- ✓ Presence of active vitamin D that increase calbindin, Ca^{++} channels and Ca^{++}- ATPase.

Absorption of Iron

Forms of Iron:

- Iron of plant sources mainly in the form of ferrous iron.
- Heme iron of animal sources in form of hemoglobin and myoglobin.

Absorption at luminal border:

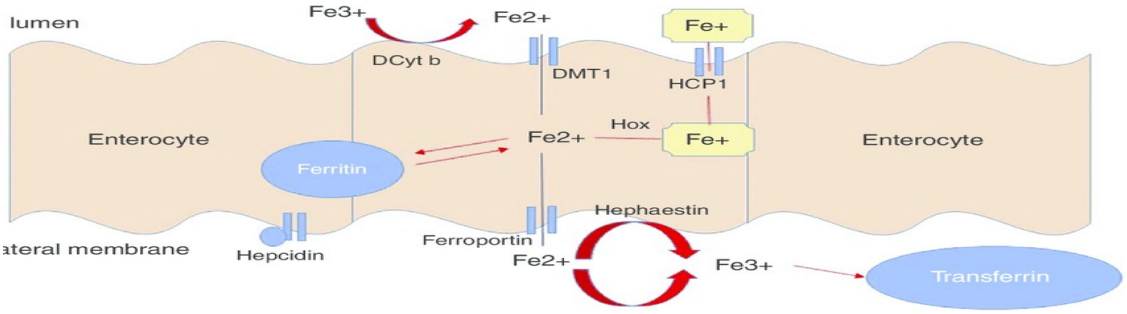
- Heme iron is absorbed by heme carrier protein- 1 (needs energy) and then extracted inside the cell by enzymes.
- Ferric iron is converted first to ferrous iron and then transported by energy dependent carrier (divalent metal transporter-1- DMT)

Absorption at basal border:

- The unneeded iron is stored inside enterocytes in form of ferritin that could be lost after mucosal sloughing.
- The needed iron transported by iron transporter called feroportin 1, then transported in plasma bound to transferrin.

N.B.:

- ✓ Iron absorption is regulated according to body need. This is done by a hormone named hepcidin (released by liver) that bind with feroportin 1 prevent iron absorption.
- ✓ So iron absorption is increased by increased body demands as in anemia, HCL and ascorbic acids are needed as it convert ferric to ferrous iron.



https://www.researchgate.net/profile/Adrian_Santoyo-Sanchez/publication/285672578/figure/fig2/AS:404130163118081@1473363547079/Haem-and-non-haem-iron-absorption-pathways-duodenal-enterocytes.png

Absorption of Vitamins

1- *Absorption of fat-soluble vitamins* (A, D, E, K):

- ✓ They are carried in micelles and absorbed passively with digestion products of fat.

2- *Absorption of water-soluble vitamins*:

- ✓ As thiamin, pyridoxin and ascorbic acids, they are absorbed mostly by Na^+ depend cotransporters. Except for vitamin B12 and folate absorption that is not Na^+ dependent.
- ✓ Vitamin B12 and the intrinsic factor secreted from stomach (parietal cell) is absorbed by receptor mediated endocytosis in terminal ileum.

N.B.:

- Vitamin B12 deficiency leads to pernicious anemia, it can be due to intrinsic factor deficiency as in atrophic gastritis or surgical resection of ileum.
- Deficiency of fat digestion enzyme especially pancreatic lipase and fat absorption can lead to deficiency of fat-soluble vitamins.

Absorption of Water

It occurs by osmosis depending on Na+ absorption.
As Na^+ absorption create high osmotic pressure in interstitial spaces, increasing H_2O movement through cell membrane and in between cells. So hydrostatic pressure increases pushing the water to blood capillaries.

Water Turnover over the GIT

Amount of water entering the small intestine =
9000 ml (2000 ml ingested + 7000 ml GIT secretion)
Small and Large intestine absorb 8800 ml
Remaining volume 150- 200 ml is lost in feces.
N.B.:
Plasma is the source of digestive juices
Recurrent vomiting or Diarrhea can lead to dehydration and shock.

Factors affecting intestinal absorption:

1) Vitality of intestinal mucosa.
2) State of digestion.
3) Bile salts & lymph flow.
4) Duration of contact of food to intestinal mucosa.
5) Intestinal mixing movements.
6) Surface area available for absorption.
7) Movements of the villi.
8) Physico-chemical factors.

N.B.:

1) loss of villi in a disease like celiac disease (gluten sensitivity) lead to loss of absorptive power of intestine. Sensitivity is to gluten part of wheat and relieved by intake of gluten free food.

2) resection of > 50% of small intestine greatly affect the absorptive power of small intestine.
3) Loss of one of the digestive juices as bile will lead to indigestion of fat with also loss of fat-soluble vitamins.
4) Paralytic ileus is paralysis of small intestinal motility with loss of absorptive power of intestine.